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MAGNETIC FIELD EFFECT ON DONOR BIDING ENERGY IN A MODULATED NANOWIRE

C. Gómez-Olejua [1], F. A. Rodriguez-Prada [1], H. Paredes [1], Carlos L. Beltrán Ríos [1]*

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- ✓ Este suplemento constituye las memorias del congreso "*X Iberoamericano de Metalurgia y Materiales (X IBEROMET)*" celebrado en Cartagena, Colombia, del 13 al 17 de Octubre de 2008.
- ✓ La selección y arbitraje de los trabajos que aparecen en este suplemento fue responsabilidad del Comité Organizador del *X IBEROMET*, quien nombró una comisión *ad-hoc* para este fin (véase editorial de este suplemento).
- ✓ La *RLMM* no sometió estos artículos al proceso regular de arbitraje que utiliza la revista para los números regulares de la misma.
- ✓ Se recomendó el uso de las "Instrucciones para Autores" establecidas por la *RLMM* para la elaboración de los artículos. No obstante, la revisión principal del formato de los artículos que aparecen en este suplemento fue responsabilidad del Comité Organizador del *X IBEROMET*.

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Resumen

Hemos calculado la energía de enlace de una impureza donadora localizada en un pozo cuántico dentro de una heteroestrutura de nanohilo modulado de forma cilíndrica, como función de la posición de la impureza, el tamaño de la estructura y de un campo magnético aplicado en la dirección de crecimiento. Los calculos son realizados dentro de la aproximación de la masa efectiva y usando el método de la dimensión fractal. Nuestros resultados son comparados con reportes previos.

Palabras Claves: *Impureza Donadora, Energía de Enlace, Campo Magnético, Nanohilo*

Abstract

We calculated the ground state binding energy for a donor impurity localized in a GaAs quantum well of a modulated cylindrical nanowire heterostructures as a function of the impurity position, system size and an applied magnetic field in the growth direction. Calculates are obtained in the effective mass approximation work frame and using the fractal dimension method. Our results are compared with previous reports.

Keywords*: DonorImpurity, Binding Energy, Magnetic Field, Nanowire*

1. INTRODUCCION

In the last years have been fabricated new semiconductors heterostructures called modulated nanowires (MNW) [1] and nanowires superlattices (NWSL) using different methods [2]. NWSL consists of a series of interlaced nanodots of two different materials, this heterostructures have generated differents applications in nanoelectronics and photonics [1-4]. This systems show radically different, from plain nanowires and quantum-well structures, in their electronic, transport and optical [5, 6] properties. Zhang et al. [7] found that for the case of resonant ac electric field applied to NWSL, the coherent dynamics is much more complex as compared to the standard two-level description. Galeriu et al. [8] modelling the electron states in a GaAs/AlGaAs NWSL semiconductors using different numerical methods. Persson y Xu [4] used an atomistic tight binding model studied the miniband formation for GaAs/GaAlAs NWSL. M. Niquet [9] used a semiempirical tight-binding model including piezoelectric effects and the electron-hole interaction. D. S. Citrin [10] have studied the Magnetic Bloch Oscillations a NWSL ring, he discuses the presence of Wannier states in this system.

2. THEORETICAL MODEL

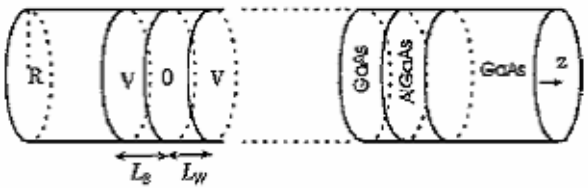


Figure 1. Nanowire Superlattice Scheme

We considered a cylindrical NWSL of R radii, a scheme of the NWSL is show in figure 1. The GaAlAs width layer (Lb) are considered greater that the width of the GaAs layer (Lw), Lw << Lb, with this approximation let us to take the GaAs layer with a single quantum well (QW) with GaAlAs barriers in the axial direction and a

magnetic field is applied in z-direction. The ground state binding energy of an impurity, localize in the QW, is analyze as a function of the impurity position and the dimension of the wire. The Schrödinger equation in dimensionless units for the energy and length is

$$\left[-\nabla^2 + V(\rho,z) + \frac{\gamma^2}{4}\rho^2 - g^*\gamma - \frac{2\tau}{\sqrt{\rho^2+(z-z_i)^2}}\right]\Psi(\rho,z) = E\Psi(\rho,z) \quad (1)$$

The $V(\rho,z)$ is the potential confinement, given by

$$V(\rho,z) = \begin{cases} 0, |z| \le \frac{Lw}{2} \wedge \rho < R; \\ V_0, |z| > \frac{Lw}{2} \wedge \rho < R; \\ \infty, \rho > R \end{cases} \quad (2)$$

We used the a trial wave function give by

$$\Psi(\rho,z) = \Phi(\rho,z)G(r) \quad (3)$$

Where $\Phi(\rho,z) = f(z)R(\rho)$ is the solution when τ=0, and *G(r)* take in account the effect of the coulomb term in Eq. 1 ($\tau \neq 0$). Using the variational Schrödinger method [11-13] we obtain the differential equation

$$-\frac{1}{J(r)}\frac{d}{dr}\left[J(r)\frac{d}{dr}G(r)\right] + \frac{2}{r}G(r) = E_b G(r) \quad (4)$$

Where *J(r)* is the Jacobian of the system [11, 12] and E_b is the binding energy of the impurity. The equation (4) is solved using the trigonometric sweep method [12].

3. RESULTS AND DISCUSSION

Our result are present in effective units of the length (a_0*) and energy (Ry*), the dielectric constant and the effective mass for the electron is the same for both well and barrier material. In the limit cases of the QW (R>>Lw),and Quantum Well Wire, QWW (Lw >>R), our result are in good agreement with previous reports [14-17].

In figure 2 and 3 we present the Binding Energy for a donor impurity as a function of the applied magnetic field for different dimensions of the Nanowire (figure 2) with the impurity centred in the well and different impurity position (figure3). Figure 2 show the effect of the confinement: the energy is increase when the geometrical confinement is increasing. Figure 3 show as the energy is increasing when the impurity is localized, far away of the barrier, in different position on z-axis. In both cases the magnetic field is increasing the energy when the impurity is localized, far away of the barrier, in different position on z-axis. In both cases the magnetic field is increasing the energy.

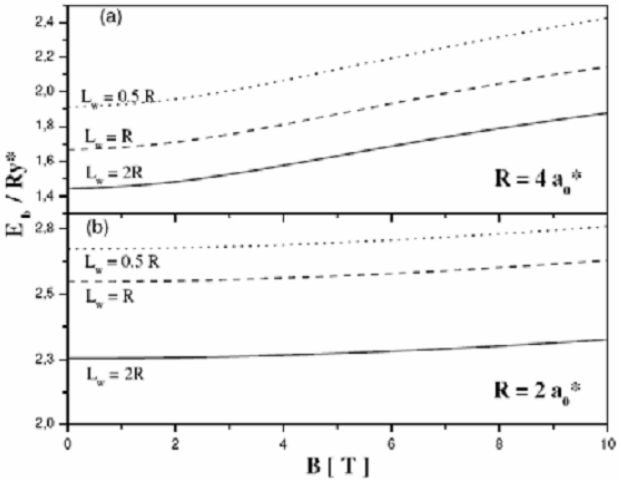


Figure 2. Binding Energy for a donor imputity centered in the well as a function of the magnetic field.

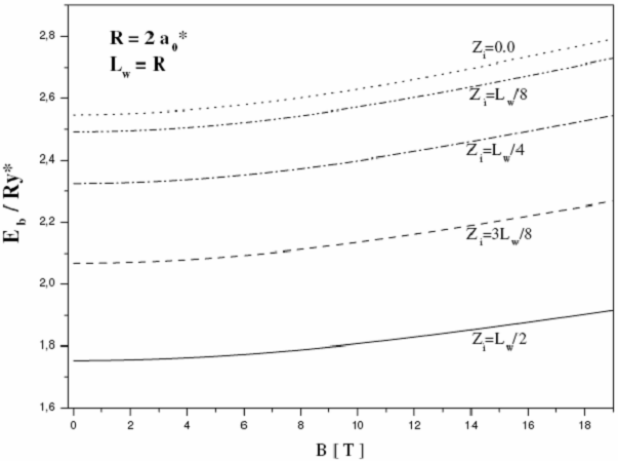


Figure 3. Binding Energy for a donor impurity as a function of the magnetic field and different positions of the impurity.

In figure 4 we present the Biding energy as a function of the impurity position and different values of the magnetic field, for two different geometrical dimensions of the structures: Figure 4a

corresponds to R=4a*$_0$ and L=2R, and Figure 4b for R=2 a*$_0$ and L =2R, . In the figure it can be observe the competition between geometrical and magnetic confinement. In Fig 4a the magnetic confinement is predominating on the geometrical confinement, in Fig 4b the situation is the opposite; the effect of the magnetic field is lower that in the other situation, but the confinement is bigger and the energy is increasing.

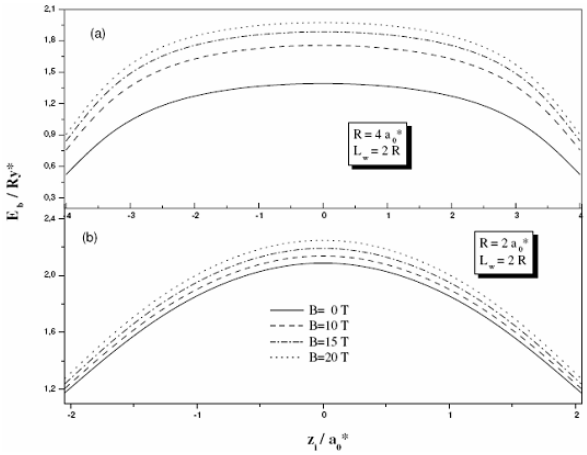


Figure 4. Binding energy for a donor impurity as a function of its position and different values of the magnetic field, and dimension of the structure.

4. CONCLUSIONS

In summary we had calculated the Binding Energy for a donor impurity in a single modulated nanowire within effective mass approximation and using a variational procedure, with an applied magnetic field. Our results show the effect of the geometric and magnetic confinement increase the energy from the limit cases: QW and QWW.

5. REFERENCES

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